

1 1. A device for detecting a specific material that
2 may be present in an ensemble of objects comprising means to
3 expose an area of the ensemble to x-ray energies to produce
4 dual energy image information of the ensemble and means to
5 computer-process such dual energy information to detect said
6 specific material on the basis of comparisons of selected
7 subareas of said exposed area to other subareas in the
8 vicinity of said selected subareas.

1 2. A device for detecting a bomb that may be
2 present in a container of objects comprising means to expose
3 an area of the container to x-ray energies to produce dual
4 energy image information of the container and its contents
5 and means to computer-process such dual energy information
6 to detect said bomb on the basis of comparisons of selected
7 subareas of said exposed area to other subareas in the
8 vicinity of said selected subareas.

1 3. A device for detecting a specific material that
2 may be present in an ensemble of objects comprising means to
3 expose an area of the ensemble to x-rays of at least two
4 substantially different energy bands to produce dual energy
5 image information of the ensemble and means to computer-
6 process such dual energy information to detect said specific
7 material on the basis of comparisons between attenuation
8 image information from at least one of said energy bands and
9 positionally corresponding image information of parameter P
10 values derived from correlations of said dual energy image
11 information with values in a predetermined lookup table
12 reflecting attenuation at high and low energy bands over a
13 range of thicknesses of a selected specific material and a
14 range of thicknesses of a representative overlay material,
15 with attenuation of a constant thickness of said overlay

16 material and varying thicknesses of said specific material
17 represented by said parameter P.

1 ~~4~~ 4. The device of claim ~~3~~ ⁴ wherein the means to
2 computer-process includes means for evaluating gradients of
3 values in at least one of the images.

1 ~~5~~ 5. The device of claim ~~4~~ ⁴ wherein the means to
2 computer-process includes means for evaluating gradients of
3 values in both said attenuation image and said image of P
4 values.

1 ~~6~~ 6. The device of claim ~~4~~ ⁴ having means for selecting
2 the regions of said attenuation image information for said
3 comparisons on the basis of the steepness of gradients of
4 attenuation values in said attenuation image.

D 1 ~~7~~ 7. The device of claim ~~4, 5 or 6~~ ⁶ wherein said means
2 for selecting employs an edge finding operator.

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L 1 ~~8~~ 8. The device of claim ~~6~~ ⁶ including means for
2 generating gradient values H_s for substantially all subareas
3 and means for pruning to remove subareas with H_s values
4 below a selected threshold, and means for thereafter
H 5 performing said comparisons using the remaining H_s values.

R 1 ~~9~~ 9. A device for detecting and indicating the
2 probable presence of a specific material in an ensemble of
3 objects, comprising
4 means for exposing said item to x-rays of at least
5 two substantially different energy levels,

P₁ 6 means for generating for each subarea over the
7 exposed area a set of data values representing logarithms of
8 x-ray attenuation at said subarea at each of said energy
9 levels,

P₁ 10 means for processing said data for said subarea to
11 compute the values of (H,L) for said subarea, wherein H is
12 the logarithm of the attenuation of said x-rays at said
13 subarea at the higher energy level and L is the logarithm of
14 the attenuation of said x-rays at said subarea at the lower
15 energy level, and

P₁ 16 means for applying an edge finding or gradient
17 evaluating operator such as a Sobel operator to image data
18 of at least one energy level,

P₁H₁ 19 means for generating gradient values H_g for
20 substantially all subareas,

P₁H₁ 21 means for pruning to remove subareas with gradient
22 values H_g below a selected gradient threshold,

P₁H₁ 23 means for determining for remaining subareas with
24 gradient values H_g above said selected gradient threshold
25 parameter P values using a lookup table in computer storage
26 reflecting x-ray attenuation at high and low energy bands
27 over a range of thicknesses of said selected specific
28 material and a range of thicknesses of a representative
29 overlay material, with attenuation of a constant thickness
30 of said overlay material and varying thicknesses of said
31 specific material represented by said parameter P,

P₁ 32 means for applying said gradient evaluating operator
33 to P image data formed using said parameter P values for
34 said remaining subareas,

P₁H₁ 35 means for generating gradient values P_g for said
36 remaining subareas,

$P_1 H$ 37 means for calculating a ratio H_s/P_s for said
38 remaining subareas,
 P_1 39 means for raising said ratio to a power at least as
40 large as unity to emphasize large values of said ratio, and
 $P_1 H$ 41 means for storing said ratio H_s/P_s raised to said
42 power for substantially all of said remaining subareas.

P_1 1 ~~10.25~~ 10. The device of claim ~~9~~ further comprising
2 means for selecting an alarm threshold on said ratio
 H 3 H_s/P_s raised to said power so that subareas having said
 L 4 ratio H_s/P_s raised to said power above said alarm threshold
5 are strongly indicative of presence of said specific
6 material,
 P_1 7 means for applying a dilation algorithm using said H
8 values and said L values for said image data,
 P_1 9 means for sounding an alarm if a certain number of
10 subarea values are above said alarm threshold,
 P_1 11 means for applying an erosion algorithm to eliminate
12 spurious noise in said image data, and
 P_1 13 means for displaying said image data with areas of
14 particular interest highlighted.

P_1 1 ~~11.25~~ 11. A device for detecting and indicating the
2 probable presence of a specific material in an ensemble of
3 objects, comprising
 P_1 4 means for exposing said item to x-rays of at least
5 two substantially different energy levels,
 P_1 6 means for generating for each subarea over the
7 exposed area a set of data values representing logarithms of
8 x-ray attenuation at said subarea at each of said energy
9 levels,
 P_1 10 means for filtering said data for said subarea,

P₁ 11 means for averaging said data for said subarea,
L 12 means for processing said data for said subarea to
13 compute the values of (H,L) for said test subarea, wherein H
14 is the logarithm of the attenuation of said x-rays at said
15 subarea at the higher energy level and L is the logarithm of
16 the attenuation of said x-rays at said subarea at the lower
17 energy level, and

P₁ 18 means for applying an edge finding or gradient
19 evaluating operator such as a Sobel operator to image data
20 of at least one energy level,

P₁ H 21 means for generating gradient values H_s for
22 substantially all subareas,

P₁ 23 means for pruning to remove subareas with gradient
H 24 values H_s below a selected gradient threshold,

P₁ 25 means for determining for remaining subareas with
H 26 gradient values H_s above said selected gradient threshold
27 parameter P values using a lookup table in computer storage
28 reflecting x-ray attenuation at high and low energy bands
29 over a range of thicknesses of said selected specific
30 material and a range of thicknesses of a representative
31 overlay material, with attenuation of a constant thickness
32 of said overlay material and varying thicknesses of said
33 specific material represented by said parameter P,

P₁ 34 means for applying said gradient evaluating operator
35 to P image data formed using said parameter P values for
36 said remaining subareas,

P₁ H 37 means for generating gradient values P_s for said
38 remaining subareas,

P₁ H 39 means for calculating a ratio H_s/P_s for said
40 remaining subareas,

P₁ 41 means for raising said ratio to a power at least as
42 large as unity to emphasize large values of said ratio,

P₁ H 43 means for storing said ratio H_s/P_s raised to said
P₁ 44 power for substantially all of said remaining subareas,
45 means for selecting an alarm threshold on said ratio
H 46 H_s/P_s raised to said power so that subareas having said
L 47 ratio H_s/P_s raised to said power above said alarm threshold
48 are strongly indicative of presence of said specific
49 material,
P₁ 50 means for applying a dilation algorithm using said H
51 values and said L values for said image data,
P₁ 52 means for sounding an alarm if a certain number of
53 subarea values are above said alarm threshold,
P₁ 54 means for applying an erosion algorithm to eliminate
55 spurious noise in said image data, and
P₁ 56 means for displaying said image data with areas of
57 particular interest highlighted.

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1 12. A device for inspecting an ensemble of physical
2 objects comprising means to expose an area of said ensemble
3 to x-rays of at least two substantially different energy
4 bands, detection means responsive to said x-rays passing
5 through said ensemble to generate for subareas over said
6 area respective sets of values representing the attenuation
7 of said x-rays at each of said energy bands, comparison
8 means operative on differences in attenuation between
9 subareas in a neighborhood to determine the presence of a
10 specific material in the neighborhood, and indicating means
11 responsive to said comparisons for indicating presence of
12 said specific material in said ensemble.

1 13. The device of claim 12 wherein said comparison
2 means includes a lookup table reflecting attenuation at high
3 and low energy bands over a range of thicknesses of a

4 selected specific material and a range of thicknesses of a
5 representative overlay material, with attenuation of a
6 constant thickness of said overlay material and varying
7 thicknesses of said specific material represented by a
8 parameter P.

14. The device of claim 13 including means to
reference actual attenuation measurements of subareas at an
energy band with parameter P values for said subareas, and
using said determination in determining the presence of said
specific material.

15. The device of claim 12 wherein said comparison
means include means to combine, according to a predetermined
formula, values representing the attenuation of said x-rays
for subareas in said neighborhood to provide an attenuation
measure and means to compare said measure to a reference
related to said specific material.

16. The device of claim 12 wherein said values
generated representing the attenuation of said x-rays at
said energy bands are logarithms of x-ray attenuation at
each of said energy bands at each subarea.

17. The device of claim 12 wherein said comparison
means comprises means for computing for a selected test
subarea of said area the values (H_T, L_T) wherein H_T is the
logarithm of the attenuation of said x-rays at said higher
energy band at said test subarea and L_T is the logarithm of
the attenuation of said x-rays at said lower energy band at
said test subarea, means for computing for a subarea nearby
said test subarea the values (H_B, L_B) wherein H_B is the

Claims 33-35

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9 logarithm of the attenuation of said x-rays at said higher
10 energy band at said nearby subarea and L_B is the logarithm
11 of the attenuation of said x-rays at said lower energy band
12 at said nearby subarea, said comparison means constructed to
13 employ said values (H_T, L_T) and (H_B, L_B) in determining the
14 presence of said specific material.

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5, H, 31, 66

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1 18. The device of claim 17, further comprising means
2 for providing p-values P representing attenuation
3 characteristics of various overlying materials, means for
4 associating a p-value P_T with said values (H_T, L_T) wherein
5 said p-value P_T is proportional to the thickness of
6 overlying materials at said test subarea, means for
7 associating a p-value P_B with said values (H_B, L_B) wherein
8 said p-value P_B is proportional to the thickness of
9 overlying materials at said nearby subarea, means for
10 computing the value of $|(H_T - H_B) / (P_T - P_B)| = \Delta H / \Delta P$ and means
11 for associating $\Delta H / \Delta P$ with a relative probability measure
12 for the presence of said specific material at respective
13 subareas.

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1 19. The device of claim 18 wherein the relative
2 probability measure is proportional to $(\Delta H / \Delta P)^q$, wherein q
3 is a value chosen to emphasize extrema of the value of
4 $\Delta H / \Delta P$.

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1 20. The device of claim 19 wherein $q=2$.

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1 21. The device of claim 18 wherein said means for
2 associating a p-value P with said values (H, L) involves
3 identifying said values with respective points from a set of
4 points previously generated by numerically varying

5 thicknesses of said specific material and said overlying
6 materials.

29~~28~~ 24
22. The device of claim 21 wherein said comparison
means comprises means for computing the value of
H31 H 3 $(H_T - H_B) / (L_T - L_B) = K_{TB}$ and means for comparing said value of
H 4 K_{TB} with the value of K_{MAT} wherein K_{MAT} is an attenuation
5 characteristic of said specific material.

30~~29~~ 29
23. The device of claim 22 wherein K_{MAT} is a stored
2 value developed by prior measurements.

31~~30~~ 29
24. The device of claim 22 wherein
H, 167, 82 2 $K_{MAT} = \mu_H / \mu_L$ wherein μ_H is the attenuation coefficient of
3 said specific material exposed to said higher energy band
82H 4 x-rays and μ_L is the attenuation coefficient of said
5 specific material exposed to said lower energy band x-rays.

Sub B4
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Sub B5
25. The device of claim 12 further comprising means
for exposing selected numbers of samples of various known
materials each of a range of different thicknesses to said
x-rays of said different energy bands to measure the
attenuation characteristic of the exposed samples to provide
a reference for said comparison means.

33~~32~~ 33
26. The device of claim 25 including calculation
means for interpolating between said measured values to
estimate intermediate values for use in making said
comparison.

27. The device as in any of claims 3-26 further
comprising means for assigning to subareas over said exposed

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3 area of the object relative probabilities for the presence
4 of said specific material based upon said comparisons, said
5 indicating means being responsive to said relative
6 probability assignments for indicating presence of said
7 specific material in said object.

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28. A baggage inspection device for detecting and
1 indicating the probable presence of a specific material in
2 an item of baggage comprising means to expose an area of
3 said item to x-rays of at least two substantially different
4 energy bands, detection means responsive to said x-rays
5 passing through said item to generate for subareas over said
6 area respective sets of values representing the attenuation
7 of said x-rays at each of said energy bands, comparison
8 means operative on differences in attenuation between
9 subareas in a neighborhood to determine the presence of a
10 specific material in the neighborhood of said subareas, and
11 indicating means responsive to said comparisons for
12 indicating presence of said specific material in said item,
13 said comparison means comprising means for computing for a
14 selected test subarea of said area the values (H_T, L_T)
H 15 wherein H_T is the logarithm of the attenuation of said
L 16 x-rays at said higher energy band at said test subarea and
H 17 L_T is the logarithm of the attenuation of said x-rays at
H 18 said lower energy band at said test subarea, means for
19 computing for a subarea nearby said test subarea the values
H 20 (H_B, L_B) wherein H_B is the logarithm of the attenuation of
21 said x-rays at said higher energy band at said nearby
H 22 subarea and L_B is the logarithm of the attenuation of said
23 x-rays at said lower energy band at said nearby subarea,
24 said comparison means constructed to employ said values
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H 26 (H_T, L_T) and (H_B, L_B) in determining the presence of said
27 specific material.

P₁ H L 1 ³⁷~~29~~. The device of claim ³⁶~~28~~ wherein said comparison
2 means comprises
3 means for providing p-values P representing
4 attenuation characteristics of various overlying materials,
P₁ H L 5 means for associating a p-value P_T with said values
6 (H_T, L_T) wherein said p-value P_T is proportional to the
7 thickness of overlying materials at said test subarea, means
H L 8 for associating a p-value P_B with said values (H_B, L_B)
9 wherein said p-value P_B is proportional to the thickness of
10 overlying materials at said nearby subarea, means for
S, H, 31, 66, 66, 11 computing the value of $|(H_T - H_B)/(P_T - P_B)| = \Delta H / \Delta P$ and means
12 for associating $\Delta H / \Delta P$ with a relative probability measure
13 for the presence of said specific material at respective
14 subareas.

P₁ L 1 ³⁸~~30~~. The device of claim ^{12 32 25 37}~~13, 14, 18 or 29~~, including
2 means for examining said subareas,
3 means responsive thereto for producing values for
4 each subarea indicative of the relative probability of
5 matching said specific material,
P₁ L 6 means for displaying subareas over said area, and
7 means for highlighting those subareas having a
8 probability greater than or equal to a selected threshold
9 value of matching said specific material.

H 31 1 ³⁹~~31~~. The device of claim ³⁶~~28~~ wherein said comparison
2 means comprises means for computing the value of
H 31 3 $(H_T - H_B)/(L_T - L_B) = K_{TB}$ and means for comparing said value of

H 4 K_{TB} with the value of K_{MAT} wherein K_{MAT} is an attenuation
5 characteristic of said specific material.

82H H 1 ⁴⁰₃₂. The device of claim ²⁴₁₇ or ³⁶₂₈, wherein $K_{MAT} =$
2 $\mu_H(H_T, L_T, H_B, L_B) / \mu_L(H_T, L_T, H_B, L_B)$ wherein μ_H is an attenuation
3 coefficient of said specific material exposed to said higher
4 energy x-rays, comprising a function of the logarithms of
5 the attenuation of said x-rays at said test subarea and at
82H 6 said nearby subarea, wherein μ_L is an attenuation
7 coefficient of said specific material exposed to said lower
8 energy x-rays, comprising a function of said logarithms of
9 the attenuation of said x-rays at said test subarea and at
10 said nearby subarea.

P₁ H 1 ⁴¹₃₃. The device of claim ⁴⁰₃₂ including
2 means for ascertaining whether said value of K_{TB} is
P₁ L 3 within a selected window of values of K_{MAT} ,
4 means for incrementing a respective counter if said
H 5 value of K_{TB} is within said window,
P₁ 6 means for examining said subarea counters and
7 producing values for each subarea indicative of the relative
P₁ 8 probability of matching said specific material,
9 means for displaying subareas over said area, and
L 10 means for highlighting those subareas having a
11 probability greater than or equal to a selected threshold
12 value of matching said specific material.

14 Sub B6 1 34. The device of claim 1, 2, 3 or 12 wherein said
2 means to expose said area further comprises an x-ray source,
3 means for generating from said source x-rays of at least two
NK 4 substantially different energy bands, means for collimating

N 5 a fan beam of said x-rays, and means for conveying said
6 object to intercept said fan beam of said x-rays.

P 1 35. The device of claim 12, wherein said indicating
2 means is a visual display of an x-ray image, and said
3 indication being of the form of distinguished subareas at
4 which the specific material is probably present.

N 1 36. The device of claim 1, 2, 3, 12 or 28, wherein
2 said specific material is a threatening substance.

43 1 37. The device of claim 36, wherein said threatening
2 substance is an explosive.

K Sub 1 38. The device of claim 1, 2, 3, 12 or 28, wherein
B7 2 said specific material is an illicit drug substance.

1 39. The device of claim 1, 3 or 12, wherein said
2 ensemble comprises components of a stream of matter.

18 1 40. The device of claim 39, wherein said stream is
2 comprised of rocks and other materials, and said specific
3 material is a mineral of value.

17 1 19 41. The device of claim 39, wherein said stream is
2 shredded plastic refuse, and said specific material is a
3 particular form of plastic.

19 1 20 42. The device of claim 41, wherein said particular
2 form of plastic comprises halogenated hydrocarbon plastic to
3 be separated from other plastic refuse.

Claim 21

43. The device of claim 1, 3 or 12, wherein said ensemble comprises foodstuffs.

1 ~~22~~ ²¹ 44. The device of claim ~~43~~, wherein said foodstuffs
2 are meat, and wherein said specific material is bone.

1 ~~23~~ ²¹ 45. The device of claim ~~43~~, wherein said specific
2 material is inorganic.

1 46. The device of claim 1 or 2 further comprising
2 means for locating edges in the exposed area where one
3 material overlaps another, means for choosing subareas in
4 close proximity to said edges to be said selected subareas,
5 and means for assigning to said selected subareas a relative
6 probability for the presence of said specific materials at
7 said subareas based upon said comparisons with other
8 subareas in the vicinity, and indicating means responsive to
9 said relative probability assignment.

1 47. The device of claim 12 further comprising means
2 for locating edges in the exposed area where one material
3 overlaps another, means for choosing subareas in close
4 proximity to said edges to be said selected subareas, and
5 means for assigning to said selected subareas a relative
6 probability for the presence of said specific materials at
7 said subareas based upon comparisons with other subareas in
8 the neighborhood, said indicating means being responsive to
9 said relative probability assignment.

1 48. The device of claim 1, 2, 12, 46 or 47 further
2 comprising means for dilating indications of subareas over
3 regions whose edges have been determined to indicate the
4 presence of said specific material, wherein said dilation

Claim 24

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5 makes said regions more prominently noticeable to an
6 operator of said device, and wherein said dilation enhances
7 indication of presence of said specific material.

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1 49. A method of detecting a specific material that
2 may be present in an ensemble of objects comprising exposing
3 an area of the ensemble to x-ray energies to produce dual
4 energy image information of the exposed ensemble and
5 computer-processing such dual energy information to detect
6 said specific material on the basis of comparisons of
7 selected subareas of said exposed area to other subareas in
8 the vicinity of said selected subareas.

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1 50. A method of detecting a bomb that may be
2 present in a container of objects comprising exposing an
3 area of the container to x-ray energies to produce dual
4 energy image information of the exposed container and
5 computer-processing such dual energy information to detect
6 said bomb on the basis of comparisons of selected subareas
7 of said exposed area to other subareas in the vicinity of
8 said selected subareas.

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1 51. A method of baggage inspection for detecting and
2 indicating the probable presence of a specific material in
3 an item of baggage, comprising the steps of
4 exposing said item to x-rays of at least two
5 substantially different energy levels,
6 generating for each subarea over the exposed area a
7 set of data values representing logarithms of x-ray
8 attenuation at said subarea at each of said energy levels,
9 choosing a test subarea,
10 filtering said data for said test subarea,
11 averaging said data for said test subarea,

P₁ 12 processing said data for said test subarea to
H 13 compute the values of (H_T, L_T) for said test subarea, wherein
L 14 H_T is the logarithm of the attenuation of said x-rays at
15 said test subarea at the higher energy level and L_T is the
16 logarithm of the attenuation of said x-rays at said test
17 subarea at the lower energy level, and
P₁ 18 choosing a background subarea,
L 19 filtering said data for said background subarea,
20 averaging said data for said background subarea,
21 processing said data for said background subarea to
H 22 compute the values of (H_B, L_B) for said background subarea,
L 23 wherein H_B is the logarithm of the attenuation of said
24 x-rays at said background subarea at the higher energy level
H 25 and L_B is the logarithm of the attenuation of said x-rays at
26 said background subarea at the lower energy level, and
P₁, H, 31 27 computing the value of $K_{TB} = (H_T - H_B) / (L_T - L_B)$, and
L 28 comparing said value of K_{TB} to the value of K_{MAT} ,
82L 29 wherein $K_{MAT} = \mu_H(H_T, L_T, H_B, L_B) / \mu_L(H_T, L_T, H_B, L_B)$ wherein μ_H , an
30 attenuation coefficient of a specific material exposed to
31 said higher energy x-rays, is a function of the logarithms
32 of the attenuation of said x-rays at said test subarea and
82H 33 at said background subarea, wherein μ_L , an attenuation
34 coefficient of said specific material exposed to said lower
35 energy x-rays, is a function of the logarithms of the
36 attenuation of said x-rays at said test subarea and at said
37 background subarea, and
P₁ H 38 ascertaining whether said value of K_{TB} is within a
L 39 selected window of values of K_{MAT} , incrementing a respective
P₁ L 40 counter if said value of K_{TB} is within said window,
41 choosing another background subarea, and
42 iterating the steps from filtering said data for
43 said background subarea to choosing another background

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44 subarea until a substantial number of background subareas
45 have been so examined, and
46 choosing another test subarea, and
47 iterating the steps from filtering said data for
48 said test subarea to choosing another test subarea until
49 substantially all subareas have been so tested, and
50 examining said subarea counters,
51 producing values for each subarea indicative of the
52 relative probability of matching said specific material, and
53 displaying subareas over said area, and
54 highlighting those subareas having a probability
55 greater than or equal to a selected threshold value of
56 matching said specific material.

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1 ~~51~~ 52. A method of baggage inspection for detecting
2 and indicating the probable presence of a specific material
3 in an item of baggage, comprising the steps of
4 exposing said item to x-rays of at least two
5 substantially different energy levels,
6 generating for each subarea over the exposed area a
7 set of data values representing logarithms of x-ray
8 attenuation at said subarea at each of said energy levels,
9 choosing a test subarea,
10 filtering said data for said test subarea,
11 averaging said data for said test subarea,
12 processing said data for said test subarea to
13 compute the values of (H_T, L_T) for said test subarea, wherein
14 H_T is the logarithm of the attenuation of said x-rays at
15 said test subarea at the higher energy level and L_T is the
16 logarithm of the attenuation of said x-rays at said test
17 subarea at the lower energy level, and
18 choosing a background subarea,

P_i 19 filtering said data for said background subarea,
 L 20 averaging said data for said background subarea,
 H 21 processing said data for said background subarea to
 L 22 compute the values of (H_B, L_B) for said background subarea,
23 wherein H_B is the logarithm of the attenuation of said x-
24 rays at said background subarea at the higher energy level
 H 25 and L_B is the logarithm of the attenuation of said x-rays at
 P_i 26 said background subarea at the lower energy level, and
27 providing p-values P representing attenuation
28 characteristics of various overlying materials,
 $P_i H$ 29 associating a p-value P_T with said values (H_T, L_T)
 L 30 wherein said p-value P_T is proportional to the thickness of
31 overlying materials at said test subarea,
 $P_i H$ 32 associating a p-value P_B with said values (H_B, L_B)
 L 33 wherein said p-value P_B is proportional to the thickness of
34 overlying materials at said nearby subarea,
 $P_i, S, H, 31, 66$ 35 computing the value of $|(H_T - H_B) / (P_T - P_B)| = \Delta H / \Delta P$,
 $P_i 66$ 36 associating $\Delta H / \Delta P$ with a relative probability
37 measure for the presence of said specific material at
38 respective subareas,
 P_i 39 storing said probability measure,
 L 40 choosing another background subarea, and
41 iterating the steps from filtering said data for
42 said background subarea to choosing another background
43 subarea until a substantial number of background subareas
44 have been so examined, and
 P_i 45 choosing another test subarea, and
 L 46 iterating the steps from filtering said data for
47 said test subarea to choosing another test subarea until
48 substantially all subareas have been so tested, and
 P_i 49 examining said subarea probability measure stores,

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50 producing values for each subarea indicative of the
51 relative probability of matching said specific material, and
52 displaying subareas over said area, and
53 highlighting those subareas having a probability
54 greater than or equal to a selected threshold value of
55 matching said specific material.

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1 ~~52~~ 53. A method of detecting a specific material that
2 may be present in an ensemble of objects comprising the
3 steps of
4 exposing an area of the ensemble to x-rays of at
5 least two substantially different energy bands to produce
6 dual energy image information of the ensemble, and
7 computer-processing such dual energy information to
8 detect said specific material on the basis of comparisons
9 between attenuation image information from at least one of
10 said energy bands and positionally corresponding image
11 information of parameter P values derived from correlations
12 of said dual energy image information with values in a
13 predetermined lookup table reflecting attenuation at high
14 and low energy bands over a range of thicknesses of a
15 selected specific material and a range of thicknesses of a
16 representative overlay material, with attenuation of a
17 constant thickness of said overlay material and varying
18 thicknesses of said specific material represented by said
19 parameter P.

P₁
1 ~~53~~ 54. A method of detecting and indicating the
2 probable presence of a specific material in an ensemble of
3 objects, comprising the steps of
4 exposing said item to x-rays of at least two
5 substantially different energy levels,

P_i 6 generating for each subarea over the exposed area a
7 set of data values representing logarithms of x-ray
P_i 8 attenuation at said subarea at each of said energy levels,
L 9 filtering said data for said subarea,
10 averaging said data for said subarea,
11 processing said data for said subarea to compute the
12 values of (H,L) for said test subarea, wherein H is the
13 logarithm of the attenuation of said x-rays at said subarea
14 at the higher energy level and L is the logarithm of the
15 attenuation of said x-rays at said subarea at the lower
16 energy level, and
P_i 17 applying an edge finding or gradient evaluating
18 operator such as a Sobel operator to image data of at least
19 one energy level,
P_i H 20 generating gradient values H_s for substantially all
21 subareas,
P_i H 22 pruning to remove subareas with gradient values H_s
23 below a selected gradient threshold,
P_i 24 determining for remaining subareas with gradient
H 25 values H_s above said selected gradient threshold parameter P
26 values using a lookup table in computer storage reflecting
27 x-ray attenuation at high and low energy bands over a range
28 of thicknesses of said selected specific material and a
29 range of thicknesses of a representative overlay material,
30 with attenuation of a constant thickness of said overlay
31 material and varying thicknesses of said specific material
P 32 represented by said parameter P,
33 applying said gradient evaluating operator to P
34 image data formed using said parameter P values for said
P_i H 35 remaining subareas,
36 generating gradient values P_s for said remaining
37 subareas,

$P_i H$ 38 calculating a ratio H_s/P_s for said remaining
 P_i 39 subareas,
40 raising said ratio to a power at least as large as
 $P_i H$ 41 unity to emphasize large values of said ratio,
42 storing said ratio H_s/P_s raised to said power for
 $P_i H$ 43 substantially all of said remaining subareas,
44 selecting an alarm threshold on said ratio H_s/P_s
45 raised to said power so that subareas having said ratio
 H 46 H_s/P_s raised to said power above said alarm threshold are
47 strongly indicative of presence of said specific material,
 P_i 48 applying a dilation algorithm using said H values
 P_i 49 and said L values for said image data,
 P_i 50 sounding an alarm if a certain number of subarea
51 values are above said alarm threshold,
 P_i 52 applying an erosion algorithm to eliminate spurious
 P_i 53 noise in said image data, and
54 displaying said image data with areas of particular
55 interest highlighted.

Sub
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1 55. The method as in any of claims 49-54 further
2 comprising employing computed tomographic information to
3 detect said specific material that may be present in
4 subareas indicated by said computer-processed dual energy
5 information as being probable subareas for the presence of
6 said specific materials.

1 56. For use in detecting a specific material that
2 may be present in an area being exposed to x-ray energies, a
3 lookup table in computer storage reflecting x-ray
4 attenuation at high and low energy bands over a range of
5 thicknesses of said selected specific material and a range
6 of thicknesses of a representative overlay material, with

Claim 54

7 attenuation of a constant thickness of said overlay material
8 and varying thicknesses of said specific material
9 represented by a parameter P.

Add
Bill

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